Original Article

Comparison of Sagittal Condylar Guidance Angle Obtained by Radiographic Methods and Manual Programming of Articulators in Dentate Patients – A Clinico-radiographic Study

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Abstract

Background: The ultimate goal of advanced procedures in prosthetic dentistry is to construct a prosthesis based on the accurate reproduction of condylar guidance. **Aim:** To compare the sagittal condylar inclination obtained using the cone-beam computed tomography (CBCT), panoramic image, and two articulator systems. **Settings and Design:** A cross-sectional study was carried out in 20 dentate patients in the age group of 20–40 years. **Materials and Methods:** Sagittal condylar guidance angles (SCGAs) were measured on two semi-adjustable articulators (Hanau Wide Vue and Denar Mark 320) using protrusive interocclusal record. SCGAs were also measured on the CBCT scans (CBCT reconstructed panoramic image and CBCT sagittal cross section) and the panoramic images obtained from the patients. The angles were determined on the radiographs by joining two lines: Frankfort's horizontal plane and the other plane were drawn by connecting the superior-most point on the glenoid fossa and the inferior-most point on the articular eminence. All the measurements were done twice by two operators independently. **Statistical Analysis Used:** The data were analyzed using the paired *t*-test and Pearson's correlation coefficient with a $P \leq 0.05$. **Results:** There was no significant difference between the right and the left side in any of the groups ($P \geq 0.05$). In addition, there was no significant difference between the clinical methods ($P \geq 0.05$). However, there was a significant difference between the clinical and the radiographic methods ($P \leq 0.05$). Furthermore, there was a strong correlation between the clinical and radiographic methods with Pearson's Correlation coefficient above 0.67. **Conclusion:** There is a strong correlation between the clinical and radiographic methods. Thus, CBCT and OPG can be used an adjunct to clinical methods to record sagittal condylar guidance.

Keywords: *Condylar guidance, cone-beam computed tomography, interocclusal protrusive record, radiographs*

Introduction

The ultimate goal of advanced procedures in prosthetic dentistry is to construct a prosthesis based on the accurate reproduction of condylar guidance. Condylar guidance is defined as the mandibular guidance generated by the condyle and articular disk traversing the contour of the articular eminence.[1] In prosthodontics, this mechanical form of condylar guidance, which is a primary requisite of an articulator, is adjusted by individual protrusive interocclusal registrations.[2] Christensen and Slabbert have dictated "perhaps there is no single and well defined condylar guidance *in vivo*."[3]

Many clinicians use the mean values of condylar inclination (ranging from 22° to 65°).[4-6] However, the condylar path is unique and peculiar to each individual patient varying from one person to another and also from one side to another side. Mainly, it affects the angulation of the cusps of the teeth in both protrusive and lateral excursive movements. A steep condylar inclination allows steeper inclines on the cusps of the teeth, while a less steep inclination demands a flatter occlusal surface with shallower cuspal inclination. If the articulator condylar path is set at a steeper angle than that which exists in the patient, the resulting restoration will have cusps that have overly steep inclines and vice versa.

Various arcon and nonarcon articulator systems have been used to record the condylar inclinations like Hanau H2

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and Hanau Wide Vue, Whipmix and Denar.[7] Condylar guidance can also be measured from radiographs which was introduced by Corbett *et al*.,[8] Ingervall,[9] and Christensen and Slabbert[3] to overcome the drawbacks of clinical methods. The risk of patient radiation exposure with added expenses has led to arguments toward the use of advanced radiographic imaging modalities in prosthodontics. However, higher level of accuracy and the ultimate patient benefit warrants the use of advanced radiographic methods in prosthodontics. If a correlation can be established between clinical and radiographic methods, the necessity of performing elaborate recording procedures can be eliminated and a correct value can be estimated directly from the diagnostic radiographs. However, there is no consensus in the literature, which compares the existing methods, and cone-beam computed tomography (CBCT) and studies that have been done for comparing sagittal condylar guidance angle (SCGA) using two articulator systems are scarce. Therefore, this novel study aimed to evaluate the difference in the condylar guidance obtained using the various clinical and radiographic methods. The null hypotheses were as follows:

- There will be no difference in the SCGA values on the right and the left sides
- There will be no difference between all the clinical and radiographic methods.

Materials and Methods

A total of 20 dentate patients in the age group of 20–40 years were included in the study after obtaining an approval from the Institutional Ethics Committee (MCODS/IEC/16100/October 17, 2016). This study was done in accordance with the Helsinki Declaration. A written informed consent was also obtained from the patient. The sample size was calculated taking into consideration previously done similar studies. Only patients who had a minimum of three posterior teeth in each quadrant, Class I molar with no history of orthodontic treatment and skeletal or facial malformations were included in the study. Patients with poor general health, poor neuromuscular control with signs and symptoms of temporomandibular disorders and patients who were contraindicated for radiation exposure were excluded from the study. The SCGA was measured in all the patients using two clinical and two radiographic methods with the study design, as shown in Figure 1.

Two sets of maxillary and mandibular alginate impressions (Coltoprint, Coletene, Whaledent USA) were made and poured with Type III dental stone (Kalabhai Karson Pvt. Ltd., India) to obtain the two sets of maxillary and mandibular casts to be mounted on two articulators. Hanau Spring bow that uses orbitale as the third point of reference was used with the Hanau Wide Vue articulator. Denar Slidematic facebow that uses 43 mm above the incisal edge of the lateral incisors as a third point of reference was used with Denar Mark 320 articulator. Facebow registrations were made for both the articulators following the instruction manual [Figure 2a and b] and transferred to both the articulators following zeroing of the articulators.

A prefabricated Lucia jig fabricated using heat cure clear PMMA (Coltene, Whaledent, USA) was used as an anterior deprogrammer for the muscles. It was relined with impression compound (Samit, Dentokem India) to fit the maxillary central incisors precisely [Figure 3]. The patient was trained to close in centric relation. A bite registration material, Imprint bite (3M ESPE, St. Paul, MN, USA) was syringed between the posterior teeth whiles the patient maintained firm compression against the anterior stop. The bite material was allowed to set for 1 min and retrieved [Figure 4]. To make the protrusive record, the patient was trained to move the mandible forward till the teeth were in an edge-to-edge relationship [Figure 5]. The bite registration material Imprint bite (3M ESPE, St. Paul, MN, USA) was injected to record the protrusive bite [Figure 6]. The centric relation record was used to mount the mandibular cast on the articulator [Figures 7 and 8]. Protrusive records were used to program the articulators and measure the SCGA. This angle was measured on both the right and left sides. The same procedure was repeated by a second observer for interobserver reliability and to eliminate intraobserver bias. Average values were used.

A low dose CBCT (Planmeca: ProMax 3D Mid) scan was taken for the patient at parameters 90 kV, 5.6 mA, 18 s. Exposure and images were obtained using Romexis software version 4.6.1. The interocclusal protrusive record was placed in the patient's mouth when the scan was taken. CBCT images were divided into panoramic-section and cross-section images. Based on the axial section at 4.5 mm below the superior head of the condyle, the CBCT reconstructed panoramic section was obtained with a sectioning line at the middle of both the condyles and the nasal tip [Figure 9] and the CBCT cross section was obtained by sectioning at the center of the condyle cross section in the Planmeca Romexis software [Figure 10]. The panoramic images were obtained from the patient using panoramic radiographic unit (Planmeca: ProMax 3D) with exposure parameters 70 kV, 10 mA, and 15 s.

Measuring the sagittal condylar guidance using radiographs

Cone-beam computed tomography

All the measurements were made on the Planmeca Romexis software. The Frankfurt horizontal plane was marked by joining porion (upper margin of external auditory meatus) and orbitale (lower margin of orbit). A line extending from the superior anterior most point on the glenoid fossa to the most convex inferior point on the apex of articular eminence was made. The angle between these two lines on both right and left sides was measured to obtain condylar

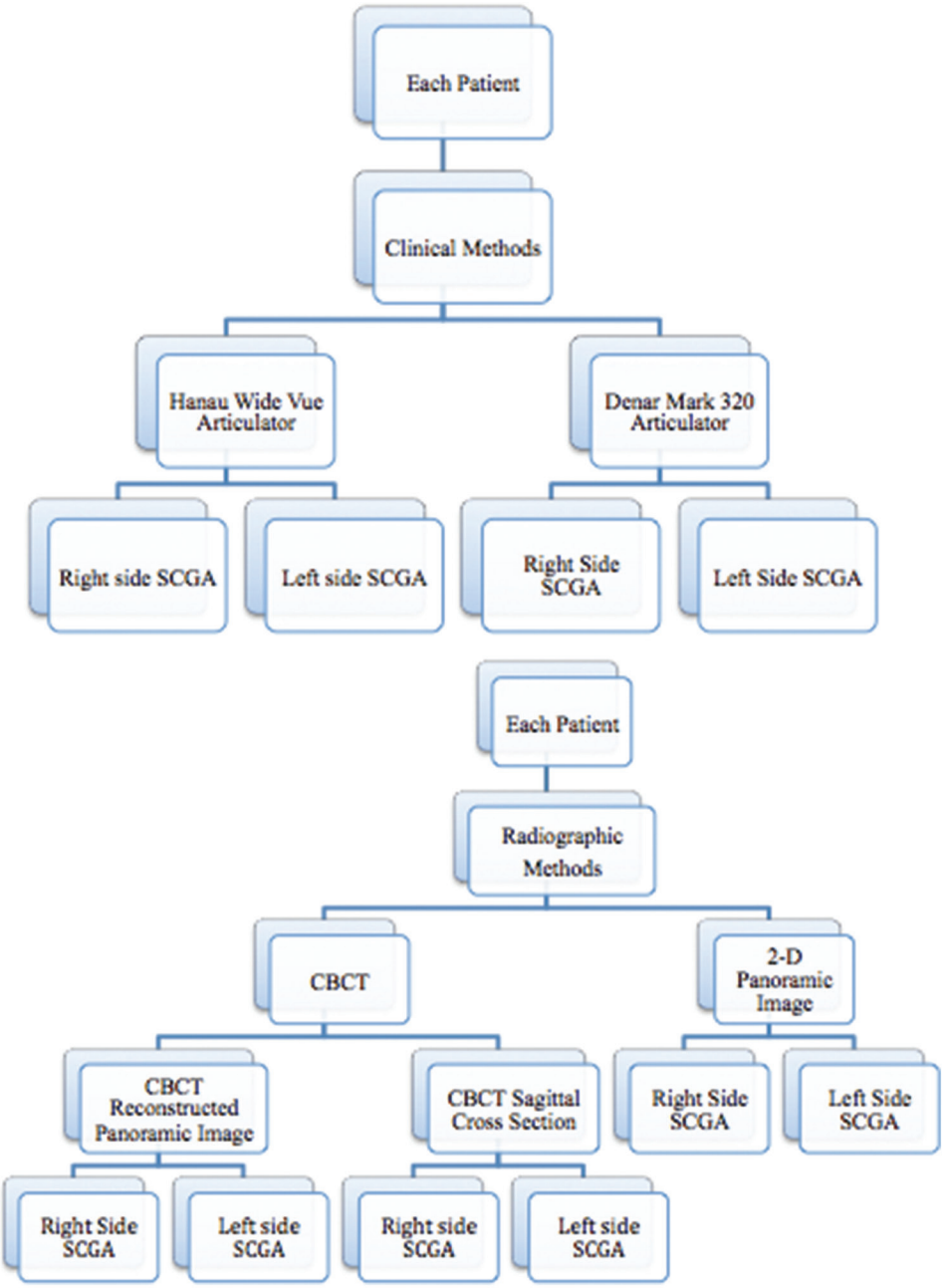

Figure 1: Flow charts representing study design

inclination angle [Figures 11 and 12]. The obtained images were saved using the software. The same method was used for both the reconstructed panoramic image and the sagittal cross section.

Two-dimensional Orthopantomogram (OPG)

Each panoramic radiograph was subjected against a radiographic illuminator. A tracing sheet was attached to the radiograph. The Frankfurt horizontal plane was drawn by joining porion (upper margin of external auditory meatus) and orbitale (lower margin of orbit) using a scale and pencil. A line extending from the superior anterior most point on the glenoid fossa to the most convex inferior point on the apex of articular eminence was made. The angle between these two lines on both right and left sides was measured to obtain condylar inclination angle using protractor and setsquares [Figure 13].

Two operators did all the measurements independently and average values were used.

The data were tabulated and were analyzed using the Statistical product for service solutions, IBM SPSS Statistics for Windows, Version 27.0. (Armonk, NY: IBM Corp). Student's *t*-test was used to compare the different clinical and radiographic methods. Pearson's correlation coefficient was used to correlate different methods on the right and

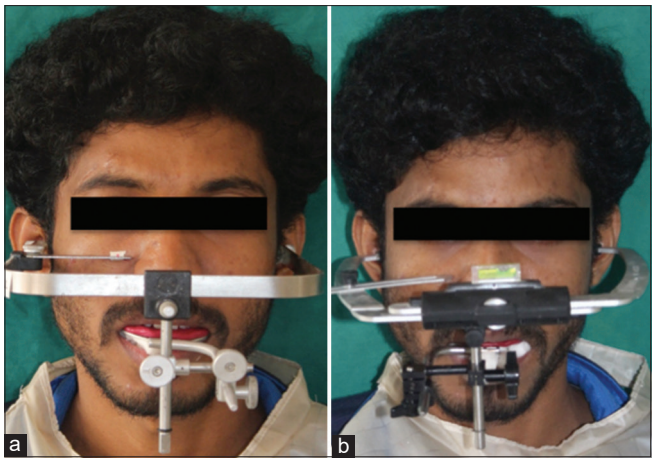

Figure 2: (a) Facebow registration using Hanau spring bow (b) Facebow registration using Denar Slidematic face bow

Figure 3: Lucia jig relined with impression compound as an anterior deprogramming device

Figure 4: Centric relation record: Intraoral frontal view

Figure 5: Intra-oral frontal view in protrusion

Figure 6: Interocclusal protrusive record: Intraoral frontal view

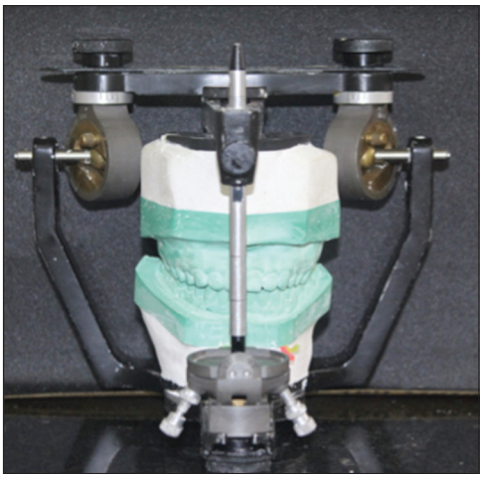

Figure 7: Mounted maxillary and mandibular casts on Hanau Wide Vue Articulator

left sides. Interclass correlation test was done to assess the interoperator reliability.

Results

The results are presented in Tables 1-3. Radiographic interpretation of SCGA gave higher values than obtained from clinical interpretation of SCGA. Two-dimensional (2D) panoramic image showed the highest SCGA value for both the right and left sides, i.e., 42.17 and 42.45°. The values obtained from clinical methods were lowest. There was statistically no significant difference in the SCGA between the right and left sides in any of the clinical or

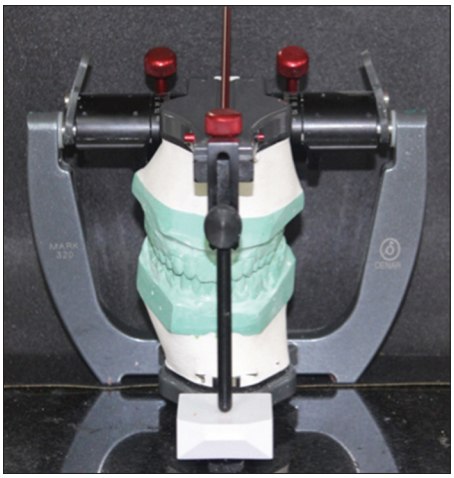

Figure 8: Mounted maxillary and mandibular casts on Denar Mark 320 Articulator

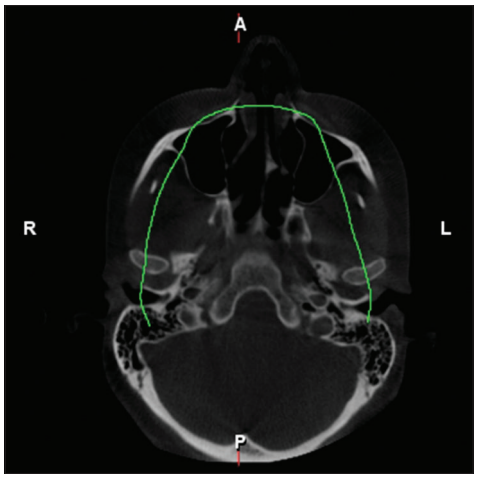

Figure 9: Cone beam computed tomography sectioning to obtain reconstructed panoramic image

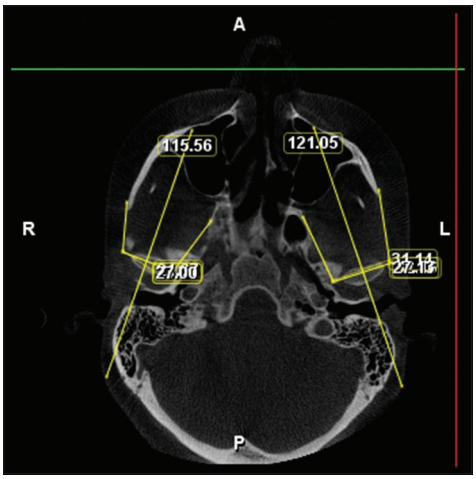

Figure 10: Cone-beam computed tomography sectioning to obtain sagittal cross-section image

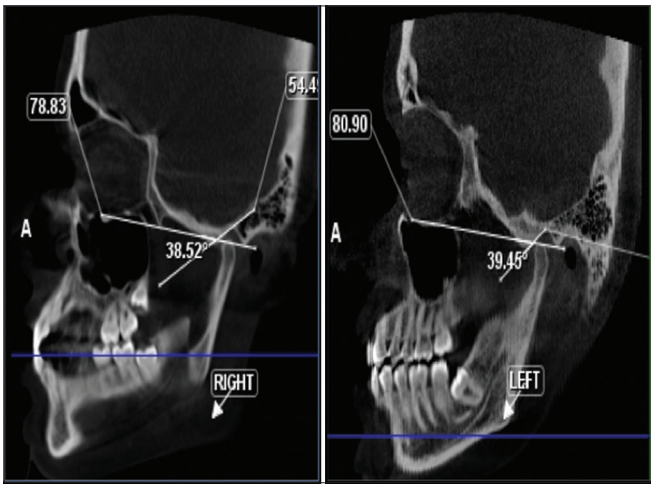

Figure 11: Sagittal condylar guidance angles on right and left sides on cone-beam computed tomography sagittal cross section

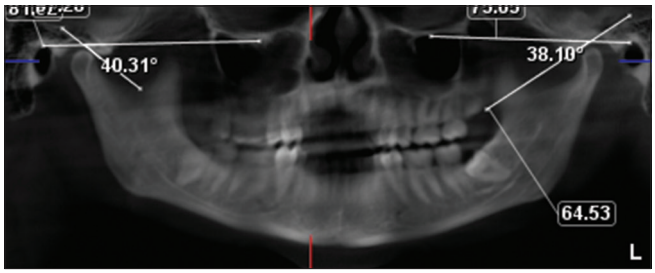

Figure 12: Sagittal condylar guidance angles on right and left sides on cone-beam computed tomography reconstructed panoramic image

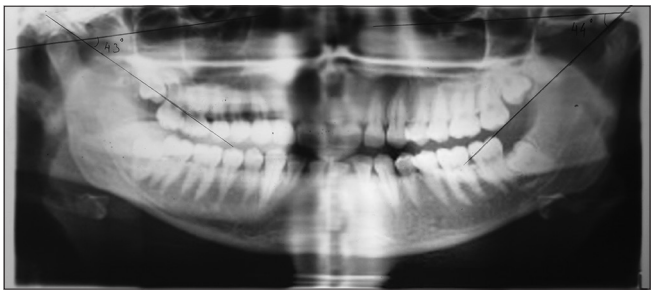

Figure 13: Sagittal condylar guidance angles on right and left sides on 2D panoramic image

radiographic methods The Cronbach's α values showed high degree of correlation between the two observers with intraclass correlation value above 0.9 and the $P < 0.001$ in all the groups [Table 1]. Table 2 shows that there was no significant difference between both the clinical methods, i.e. Hanau Wide Vue and Denar Mark 320 on both the right and left sides. There was no significant difference between the two sections of the CBCT on both the right and left sides. There was a significant difference between the clinical methods and the two sections of the CBCT on both the right and left sides. There was a highly significant difference between both the sections of the CBCT and the 2D OPG on both the right and left sides.

There was a highly significant difference between the clinical methods and the 2D OPG on both the right and left sides.

Table 1: Comparison of right and left side values of sagittal condylar guidance angle (°) in different types of methods with test for reliability between two observers

Method	Mean±SD		*t*-test (*P*)	Cronbach's α value
	Right	Left		
Hanau Wide Vue	32.75±6.57	32.86±6.27	0.825	0.961
Denar Mark 320	32.637±6.18	32.93±6.94	0.564	0.966
2D panoramic image	42.17±6.06	42.45±7.05	0.754	0.974
CBCT reconstructed panoramic image	37.33±7.68	37.44±7.47	0.905	0.972
CBCT sagittal cross section	36.65±7.53	36.61±7.62	0.921	0.983

SD: Standard deviation; CBCT: Cone-beam computed tomography system; 2D: Two-dimensional

Pearson's correlations were excellent positive and very good positive correlations (all values were above 0.6) between the SCGA values using radiographic and clinical methods, which meant that as one value increased the other also increased [Tables 2 and 3].

Discussion

All the subjects chosen in the study were in the age group of 20–40 years because the craniofacial growth is usually achieved by this age.[10] Furthermore, the sample group consisted of healthy young adults with no signs of temporomandibular joint disorders and having good neuromuscular control to ensure a physiologically normal slide of the condyle along the articular eminence.

Two semi adjustable articulators used in the study were Hanau Wide Vue and Denar Mark 320 articulators. The face bow for Hanau Wide Vue articulator is a self-aligning spring bow which uses orbitale as the anterior point of reference. The facebow for Denar Mark 320 is a slidematic type of face bow that uses a point 43 mm superior from the incisal edge of the lateral incisor or central incisor as the anterior point of reference. Weinberg[11] stated that the different anterior points of reference in different articulator systems could lower or raise the plane of occlusion by 16 mm and this affects the lateral and sagittal condylar readings which may influence the cuspal inclines but not centric relation or centric occlusion. This study showed contradictory results, as there was no significant difference in the sagittal condylar guidance obtained from the two articulators. This could be attributed to the fact that anterior reference point of the Denar face bow is located close to the level of the orbitale and the posterior reference point, which is external auditory meatus, is same in both the face bows. This could have led to the standardization of the three planar position of the maxilla on both the articulator systems. This study also showed disagreement with the results from Gross *et al*.[7] that compared the effect of three different interocclusal recording materials and their reproducibility on sagittal condylar guidance in three different articulators (Whipmix, Denar Mark II and Hanau 158). The difference in the results could be attributed to the record materials used in their study, which were inconsistent and had more potential to distort than the polyvinyl siloxane material used in this study that is more accurate and has lesser potential to distort. In addition, only two subjects participated in their study.

A protrusive record was obtained at an edge-to-edge position and the same record was used to programme both the articulators. The same relationship was maintained while taking the low-dose CBCT. According to Craddock,[12] the value of sagittal condylar guidance changes with the amount of protrusion. Hence, it is important to maintain the distance of protrusion. Posselt and Franzén[13] also suggested that there is a correlation between the degree of protrusion and its influence on the setting of condylar guidance values.

According to Davis and Mackay,[14] digital imaging along with interactive computer processing has brought a revolution to diagnostic imaging as they have added benefits of low dose of radiation exposure, better quality, accuracy, speed of application, and direct analysis. Shreshta *et al*.[2] measured the SCGA using 3D CT reconstruction, which may not be very accurate due to overlapping of structures in the articular eminence and the glenoid fossa area. Furthermore, a computed tomography image may produce variable results depending on which cross-section of the image is used for making the measurements. In the same CBCT data also, the results can vary depending on radiation dose parameters and the cross section used for analysis. Furthermore, the need to correlate the clinical readings to radiographic interpretation was considered ineluctable as the previous studies by Gross *et al*.[7] have shown that the intraoral methods have low level of reproducibility that can be attributed to variations in the materials, instruments, and operators. For standardization in the study, all the radiographs were taken at the same head position, same parameters, and on the same CBCT machine by one operator following manufacturer's instructions. This reduced the chances of image distortion and magnification.

The null hypothesis of the study was that there would be no difference in the measurements on the right and left sides was accepted. This is in accordance with the study done by Kwon *et al*.[15] where they conducted a study to compare the condylar guidance between the clinical and radiographic methods in dentulous subjects and found no difference between the right and the left sides. Studies done by el-Gheriani and Winstanley[16] and Zamacona *et al*.[17] have shown that there exists a significant difference between the sagittal condylar guidance values on the right and left sides. They believe that due to the masticatory habits of an individual, the samples can favor right side for mastication as compared to the left side which could result in more wear of the right condyle as compared to the left condyle and a flatter condyle. Hence, flatter the condyle, lesser is the condylar guidance. The reason for

Table 2: Group versus group comparison

Groups	Mean±SD	*P*	Pearson's correlation coefficient
Pair 1			
Hanau Wide Vue right	32.75±6.58	0.875	0.88
Denar 320 right	32.64±6.18		
Pair 2*			
Hanau Wide Vue right	32.75±6.58	<0.001	0.74
2D OPG right	42.17±6.06		
Pair 3*			
Hanau Wide Vue right	32.75±6.57	<0.001	0.78
CBCT - recons pan right	37.33±7.69		
Pair 4*			
Hanau Wide Vue right	32.75±6.58	0.004	0.72
CBCT sagittal cross sec right	36.65±7.53		
Pair 5*			
Denar 320 right	32.64±6.18	<0.001	0.67
2D OPG right	42.18±6.06		
Pair 6*			
Denar 320 right	32.64±6.18	<0.001	0.77
CBCT - recons pan right	37.33±7.69		
Pair 7*			
Denar 320 right	32.64±6.19	0.003	0.70
CBCT sagittal cross sec right	36.65±7.53		
Pair 8*			
2D OPG right	42.18±6.06	<0.001	0.80
CBCT - recons pan right	37.33±7.69		
Pair 9*			
2D OPG right	42.18±6.06	<0.001	0.78
CBCT sagittal cross sec right	36.65±7.53		
Pair 10			
CBCT - recons pan right	37.33±7.69	0.205	0.95
CBCT sagittal cross sec right	36.65±7.53		
Pair 11			
Hanau Wide Vue left	32.86±6.28	0.907	0.91
Denar 320 left	32.94±6.95		
Pair 12*			
Hanau Wide Vue left	32.86±6.28	<0.001	0.69
2D OPG left	42.45±7.06		
Pair 13*			
Hanau Wide Vue left	32.86±6.28	0.002	0.67
CBCT - recons pan left	37.44±7.48		
Pair 14*			
Hanau Wide Vue left	32.86±6.28	0.003	0.77
CBCT sagittal cross sec left	36.61±7.62		
Pair 15*			
Denar 320 left	32.94±6.94	<0.001	0.73
2D OPG left	42.45±7.06		
Pair 16*			
Denar 320 left	32.94±6.94	0.003	0.68
CBCT - recons pan left	37.44±7.48		
Pair 17*			
Denar 320 left	32.94±6.94	0.006	0.74
CBCT sagittal cross sec left	36.61±7.62		
Pair 18*			
2D OPG left	42.45±7.06	<0.001	0.76
CBCT - recons pan left	37.44±7.48		
Pair 19*			
2D OPG left	42.45±7.06	<0.001	0.70
CBCT sagittal cross sec left	36.61±7.62		
Pair 20			
CBCT - recons pan left	37.44±7.48	0.411	0.83
CBCT sagittal cross sec left	36.61±7.62		

*Denotes significant with $P<0.05$. CBCT: Cone-beam computed tomography system; SD: Standard deviation; 2D: Two-dimensional; OPG: Orthopantomogram

the difference from el-Gheriani and Winstanley's results can be attributed to the fact that their study population included patients who had TMJ disorders and were referred for its treatment in contrast to the study population in our study where the subjects were young healthy adults with no signs and symptoms of temporomandibular disorders. The difference in the results from the Zamacona's study could be because their sample population comprised of both completely edentulous and partially dentulous patients and was heterogeneous. In addition, they used only graphic method to record to condylar guidance. On the other hand, the sample of this study was comparatively homogeneous.

The SCGA values obtained from radiographic methods were higher than the values obtained from the clinical methods. Christensen and Slabbert[3] stated that "no radiographically determined SCGA coincided with that obtained with the use of intra-oral records. The radiographically determined angle showed a greater mean value than that determined by intra-oral records." Brewka[18] also emphasized that the clinical and radiographic values were not similar to each other and that the radiographic values were higher. Tannamala *et al*.[19] concluded in their study that the panoramic image values are higher than the clinical methods by 2°–4° but did not study any correlation between the two. Shreshta *et al*.[2] found that the CT reconstructed images had angles higher than the protrusive records by 9°–10°. Gilboa *et al*.[20] stated that on an average the radiographic values are higher by 7°. The results of this study are in accordance with the previous studies where the radiographic values are higher than the values obtained from interocclusal protrusive records. According to the results of this study, there was a very good and excellent correlation between the clinical and the radiographic methods. Hence, a clinical value of SCGA can be obtained by subtracting the value from the one measured using a radiograph.

The values in 2D OPG were higher than clinical values by 8°–10° and the CBCT values were higher by 4°–5°. The

Table 3: Interpretation of value of Pearson's correlation coefficient

0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1	Positive correlation
Poor correlation	Fair correlation	Good correlation	Very good correlation	Excellent correlation	
0–0.2	−0.2–0.4	−0.4–0.6	−0.6–0.8	−0.8–1	Negative correlation

difference between the two could be because of various reasons. First, 2D OPG is a 2D representation of 3D structures. An inherent drawback of an OPG is its distortion and overlapping of structures. Second, the OPGs were traced manually, which could incorporate human errors like difficulty in differentiation of the outline of zygomatic arch and articular eminence. The higher values obtained in CBCT could be because they represent a three-dimensional view of the stable bony landmarks.

However, the limitations of this study were a small sample size and use of only one type of interocclusal material. Further studies with larger sample size including patients with different skeletal relationships can help in better understanding.

The choice of method should be based on the clinical requirements of the prosthetic rehabilitation rather than a predominant focus on getting a precise condylar guidance angle. However, the clinical methods are more economical, practical, and also have a high degree of consistency with each other unlike radiographic methods that have limited availability in rural and semi urban areas. Hence, the importance of clinical methods to measure the sagittal condylar guidance cannot be neglected and nullified.

Conclusion

Within the limitations of this *in vivo* study, the following conclusions can be drawn:

- The SCGA obtained using CBCT is 4°–5° and with 2D OPG is 8°–10° higher than those obtained using articulators. There exists a strong positive correlation between the clinical and radiographic methods
- There is no difference in the SCGA on the right and the left sides
- CBCT and OPG can be used an adjunct to clinical methods to record sagittal condylar guidance.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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